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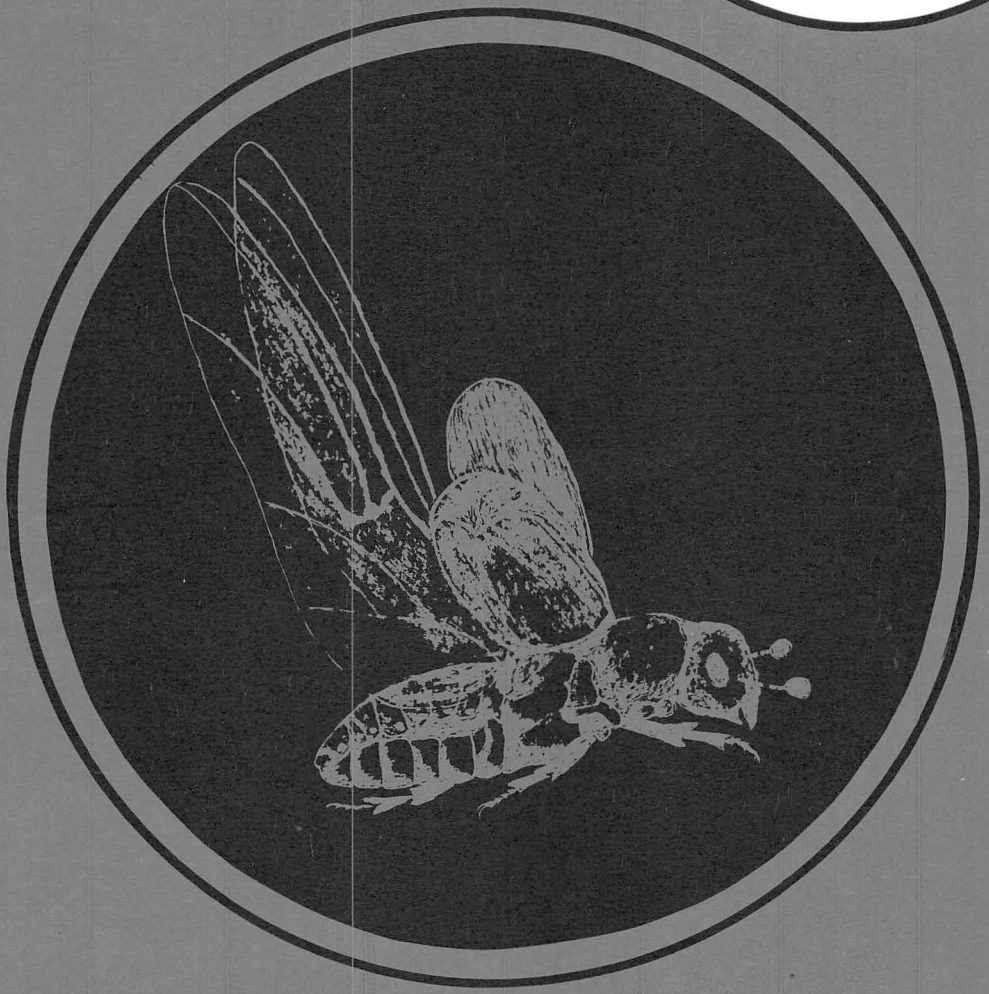

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EVALUATION OF METHYLCYLOHEXENONE (MCH) IN PREVENTING OR SUPPRESSING SPRUCE BEETLE ATTACKS IN ALASKA

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ABSTRACT

The anti-aggregation pheromone (MCH) were tested for prevention of spruce beetle infestation in felled white spruce near Granite Creek, Alaska. Liquid and granular controlled release MCH were tested at three dosage rates. In September, all progeny were larvae indicating a two-year life cycle. The best treatment, a high dosage of liquid MCH (450 mg) and a 9.2 kg/ha dosage rate of granular MCH, reduced beetle attacks and progeny by 70% and 61%, respectively when compared to the untreated controls. Factors affecting the expected release rates and inconsistencies of the MCH formulations are discussed.

INTRODUCTION

The spruce beetle, Dendroctonus rufipennis (Kirby), is the most destructive pest of white spruce, Picea glauca (Moench) Voss, and Sitka spruce, P. sitchensis (Bong.) Carr., in south-central Alaska (Werner et al. 1977). Serious outbreaks presently occur in the Chugach National Forest and Kenai National Moose Range and cover approximately 202,350 ha (Anonymous 1979, 1980, 1981). The outbreaks are believed to have resulted from windthrown trees in slash from seismic line, power line, and road rights-of-way, and from improper timber harvesting methods (Werner and Holsten 1983).

Several control techniques are presently recommended for manipulation of spruce beetle populations (Averill 1978; Holsten 1981, 1982; Werner et al. 1977; Werner 1978). Among the recommended techniques is the immediate salvage of infested trees prior to emergence of the new population, burning infested trees, treating trees with insecticides as a means of remedial or preventive control (Werner et al. 1983a, 1983b), and use of attractant baited traps to reduce beetle populations. These techniques are adequate where infestations are accessible.

Another technique is the use of synthetic attractants, inhibitors, repellents, or combinations to prevent attack or reduce the attack density to a level below the threshold density required for the development of brood trees. This type of strategy has several advantages. First, ready access to treatment areas is not necessary since aerial application of a treatment formulation might be possible. Secondly, beetle resistance to treatment, with time, would

be impossible since successful brood development would be prevented. Lastly, there would be no direct mortality to parasites and predators as occurs with insecticide treatments.

In 1974, Rudinsky et al. (1974) identified 3-methyl-2-cyclohexen-1-one (MCH), an anti-aggregant, as a major component of D. rufipennis pheromone. In his study, a 3.6% granular formulation of MCH reduced D. rufipennis attacks on Sikta spruce by 93% for five weeks. Atraction of D. rufipennis males and females was reduced 99% when MCH was added to female infested Engelmann spruce in Idaho (Kline et al. 1974). The addition of MCH (300 mg) repressed D. rufipennis attraction to synthetic pheromones and natural attractants by 99% and 87%, respectively in tests conducted on the Kenai National Moose Range, Alaska (Furniss et al. 1976). A similar study conducted in Alaska in 1977 showed that MCH was ineffective in preventing D. rufipennis attacks in felled spruce (Furniss et al. 1979). MCH was applied as a liquid in glass vials and as a controlled release granular formulation containing 2% MCH at 4.6 kg/ha. They suggested doubling the elution rate. MCH reduced D. rufipennis attacks by 50% in white spruce stumps when released from two glass vials (0.1 ml/vial) per stump (Dyer and Hall 1977). Although significantly fewer attacks occurred on treated than on untreated stumps, the attack density was not sufficiently reduced to be of practical value in controlling spruce beetle reproduction.

Results of a MCH field study initiated in the spring of 1983 to determine the efficacy of two formulations of MCH at three dosage rates each for protecting felled, uninfested white spruce from beetle attack are presented in this paper.

MATERIALS AND METHODS

Study Site: The field test was conducted in a river bottom white spruce stand along Granite Creek on the Chugach National Forest in south-central Alaska (latitude 60°45'N, longitude 149°15'W). This area is composed of mature white spruce mixed with white spruce seedlings and saplings and shrub species. Average diameter and height of dominant and co-dominant spruce were 33.5± 4.6 cm and 16.1± 2 m respectively. Beetle populations were endemic, but heavily infested spruce stands were approximately 8 km from the study site.

Treatments: The experimental design was a randomized complete-block with seven treatments per block and seven replications. Forty-nine uninfested white spruce (aver. diameter 33.5± 4.6 cm) were felled in late April along a north-south transect. Each tree was felled with the top directed eastward from the stump.

Trees within a block were 30 m apart, with 60 m between blocks. Air temperature and relative humidity were recorded hourly on a Belfort^{R} hygrothermograph placed at the midpoint of the transect. Precipitation, collected in a standard rain gauge, was recorded weekly.

Treatments consisted of a 2% controlled release granular MCH formulation[1/] applied at rates of 4.6, 9.2, and 13.8 kg/ha. These formulations were reported[2/] to have elution rates of 0.25, 0.50, and 0.75 gms MCH/ha/day;

1/ Formulation was by Zoecon Corp. 1950 Bay Rd., Palo Alto, CA.
2/ McGregor, Personal Communication, 1983.

effective for a 30-60 day period. MCH granules were applied along the top of felled trees with a hand-operated fertilizer spreader. Liquid MCH treatments were delivered in glass vials attached to wooden stakes of a height of 1.5 m. Treatments were spaced at 3 m intervals along the two sides of each felled tree (Furniss et al. 1974). The liquid MCH treatments were 150, 300, and 450 mg MCH which were reported (Furniss et al. 1974) to elute at 1-2, 2-4, and 4-8 mg/ha/day at a 3 m spacing. Felled check trees received no treatments. Uninfested trees were treated May 16 and 17 prior to beetle flight and attack. Elution rates of the liquid and granular MCH formulations were determined in a controlled environment of 21°C and 50% relative humidity for 30 days.

Each tree was baited with seudenol and alpha-pinene to attract incoming beetles to ensure that attacks would occur in the study area. The bait was delivered in a 1/2-dram polyethylene snap cap vials attached to a 1.5 m high stake placed at mid-point along the length of each tree. Trees were checked twice a week for beetle attacks. All attractants were removed as soon as attacks were noticed (June 13).

Glass vials with residual liquid MCH were collected at the end of the field season in September and weighed on a Mettler balance to determine the field elution rate.

Treatment Evaluation: Each tree was divided into three equal sections between the base and a top diameter of 20.3 cm. Bark samples from each section were collected in mid-September. Bark samples were 0.5 m - wide bands around the

circumference of the bole and located in the center of each of the three tree sections. Each bark sample was evaluated for treatment efficacy as follows: (1) number of beetle attacks per m^2; (2) number and total length of egg galleries per m^2; and (3) number and stage of beetle brood per m^2.

Analysis: Spruce beetle attacks, gallery lengths and progeny densities were subjected to a "nested" 3-way analysis of variance (ANOV); 2 cross factors (plot and treatment) and 1 "nested" factor (sample location within a tree within a treatment). Data were tested for homogeneity. If non-homogeneous, data were transformed to stabilize variance. Data were transformed, if necessary, by $y = \sqrt{x + 3/8}$ to overcome variations due to zero counts which were expected to exist in the treated trees. If 2nd order interactions were not significant, data were subjected to one-way ANOV and Scheffe's Multiple Comparison Test.

RESULTS AND DISCUSSION

Attacks were first noticed on June 13 on the felled spruce trees. Favorable temperatures for beetle flight first occurred in late May, but only for a short time (Fig. 1). Flight of beetles probably occurred from mid-June through July.

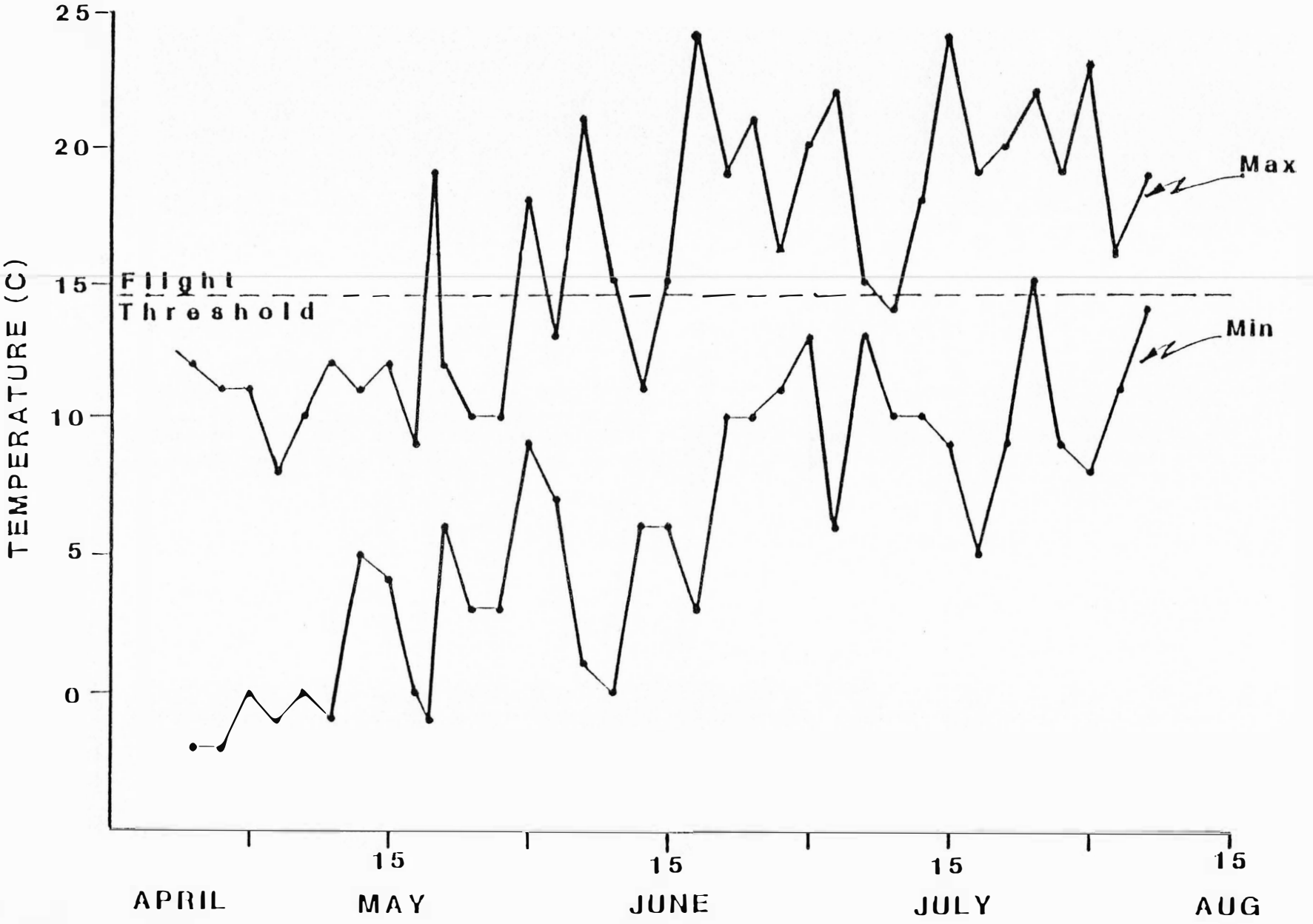

Fig. 1. Average daily maximum and minimum temperature at Granite Creek as related to flight threshold temperature for spruce beetles

The high dosage (450 mg) of liquid MCH appeared to provide the best tree protection with a 70% reduction in attacks/m^2, a 70% reduction in beetle gallery length/m^2, and a 61% reduction in progeny/m^2; as compared to the check trees (Table 1). This was closely followed by the 9.2 kg/ha dosage rate of granular MCH which resulted in a 66, 64 and 60% reduction in attacks, gallery lengths, and progeny per m^2 of bark. The high (13.8 kg/ha) and low dose (4.6 kg/ha) of granular MCH resulted in less protection. Hedden (1976) found this same relationship with the Douglas-fir beetle (D.pseudotsugae) in which attack densities were lowest at intermediate MCH levels. Bark samples contained only parent adults and larvae indicating a two-year life cycle.

However, the "nested" ANOV showed significant 2nd order interaction between plot and treatment; i.e. treatment effects were highly inconsistent between plots (Table 1). Data from plots 1, 2, and 3 were discarded as they differed, greatly in stand structure and composition when compared to the remaining plots. But, "nested" ANOV still showed significant 2nd order interaction between plot and treatment. However, position of sample location on each tree was tested as there were no significant 2nd order interactions. No significant differences were found. Thus, future sampling can be done on one location on the tree bole.

The controls, the high liquid treatment (450 mg) and the 9.2 kg/ha dosage rate of granular MCH showed, upon inspection, relatively consistent results in plots 4 through 7; the other treatments did not. As previously mentioned, these two treatments appeared to give the best reductions in number of beetle

Table 1. Average number per m^2 of spruce beetle attacks, gallery length, and progeny by treatment.

Treatment*	No. of trees	No. of samples	Av. no. attacks	Av. gallery length (cm)	Av. no. progeny
Liquid MCH 150 mg	7	21	23.7 ± 21.4	287.6 ± 162.8	601 ± 228.3
Liquid MCH 300 mg	7	21	11.1 ± 7.7	175.7 ± 129.9	601 ± 306.8
Liquid MCH 450 mg	7	21	8.5 ± 5.3	118.9 ± 64.6	490 ± 245.7
CRF 4.6 kg/ha	7	21	14.3 ± 5.6	213.3 ± 114.9	743.1 ± 280.6
CRF 9.2 kg/ha	7	21	9.2 ± 4.6	143.2 ± 175.8	500.9 ± 215.7
CRF 13.8 kg/ha	7	21	16.8 ± 8.9	235.1 ± 136.6	595.1 ± 275.1
Control	7	21	29.1 ± 13.3	396.2 ± 155	1257.5 ± 560

* Liquid MCH was placed in 1 to 3 vials at 3m spacing around felled trees. Granular controlled release formulation (CRF) was evenly spread along length of felled trees.

attacks, gallery length and number of progeny. We were able to test these treatments versus the controls with one-way ANOV as the "nested" ANOV showed no significant 2nd order interactions. These results showed that the high liquid treatment (450 mg) and the 9.2 kg/ha dosage rate of granular MCH significantly reduced attack density, gallery length, and progeny compared to the controls but not from one another ($p = .05$).

We cannot, however, state that these two treatments were statistically the "best" in terms of affecting beetle behavior due to the inconsistent "showing" of the other treatments. They did, however, appear to be the most consistent. One goal of an operational use of formulated MCH would be consistent results over a variety of spruce beetle habitat and stand types. The 9.2 kg/ha dosage of formulated MCH appeared to satisfy this goal. The use of liquid MCH in large scale studies or operations would be too cumbersome in its application.

One possible explanation for the inconsistent treatment effects is the heterogeneity in such plot characteristics as stand structure and composition. Microclimate would likewise vary considerably. Since temperature, relative humidity, and wind greatly affect the elution rate of both liquid and granular formulations of MCH, the amount of MCH eluting in the microclimate(s) surrounding the trees in a plot probably varied considerably. Likewise, the inconsistency of the environmental factors mentioned above probably affected the release rate of the synthetic attractants resulting in different amounts of beetle pressure throughout the study area, especially in plots 1-3.

As previously mentioned, the best treatments reduced attacks and progeny by approximately 70% and 61%, respectively. This was substantially better than previous Alaska spruce beetle studies where no reduction was obtained (Furniss et al. 1979) and significantly better than the 50% reduction obtained in Canada where liquid MCH was used to protect stumps (Dyer and Hall 1977). Recent studies in Idaho, however, utilized a granular controlled release formulation and reduced Douglas-fir beetle attacks by 92 to 97% and progeny by 93 to 99% (Furniss et al. 1981). Laboratory testing of both the liquid and granular MCH formulations used in the present study showed that liquid MCH eluted at rates of 1.6± 0.9, 2.9± 1.1 and 4.3± 1.3 mg/day for the three concentrations tested (Fig. 2A). The three granular formulations eluted at rates of 2.6± 2.2, 5.3± 4.2, and 10.2± 8.3 mg/day (Fig. 2B). No attempt was made to recover and re-weigh field applied granular MCH due to the difficulty in locating the material around treated trees. Samples of the liquid MCH treatments were re-weighed in September after approximately 90 days in the field. The lowest liquid MCH treatment (150 mg) in the field study eluted at only 38% of the laboratory rate (0.61 mg/day in the field vs. 1.6 mg/day in the laboratory). The release system for liquid MCH was the same for each dosage except for the number of vials (1 vs. 3), therefore, the 38% elution rate should hold true for all liquid concentrations tested. The best field results were obtained from: (1) the high dosage rate (450 mg) of liquid MCH which probably eluted closer to 1.6 mg/day instead of the expected laboratory rate of 4.3 mg/day; and (2) the middle dose of granular MCH (9.2 kg/ha) which eluted in the laboratory at a rate of 5.3± 4.2 mg/day. This would help explain the lower than expected reduction in attacks and progeny. If we assume that under field conditions the granular MCH treatments eluted

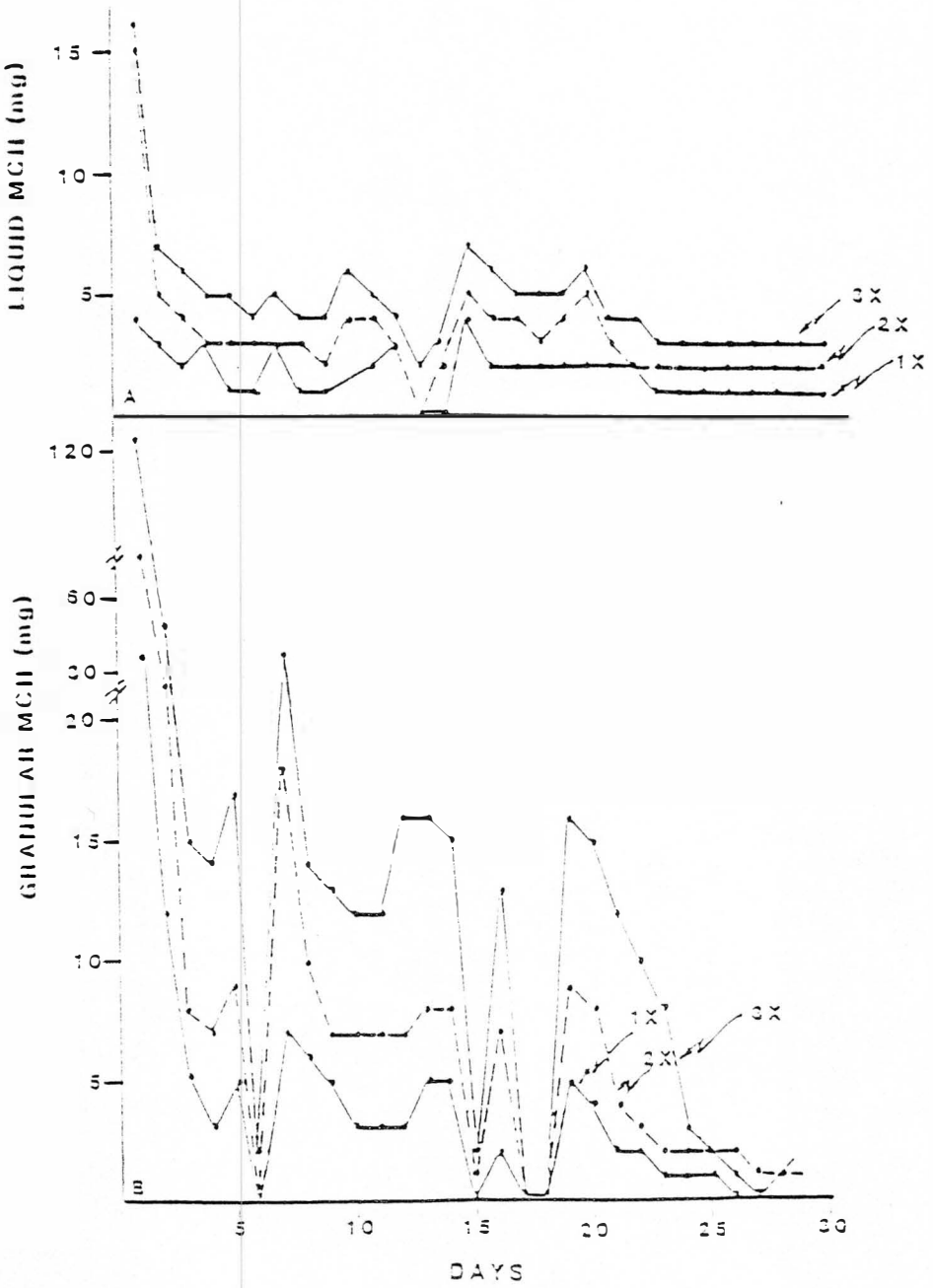

Fig. 2. Elution rates of: (A) liquid, and (B) controlled release formulation of MCH in a controlled environment of 21°C and 50% relative humidity

similarly to the liquid formulations (38%), then this mid-dose treatment eluted only 2 mg/day, similar to the high liquid treatment; theoretically it should have performed similarly, which it did. However the laboratory release rate was not uniform. There were various times when no MCH was released or was released at above average quantities (Fig. 2B). Possible explanations for this are variations in the "controlled" laboratory conditions or a "problem" with the controlled release formulation itself.

The results of this study were promising; substantial reductions in attack density and progeny were obtained. It is believed that further refinement of the 9.2 kg/ha controlled release formulation is needed to achieve 90% or above reductions, assuming that a 90% or above reduction is needed to prevent the establishment of brood trees. Field testing of other formulations and dosages are proposed for 1984. Studies will also be initiated to determine what impact beetles emerging from treated trees have on standing, live spruce. It is possible that something less than a 90% plus reduction is sufficient to prevent spruce beetle buildup in standing trees. If this proves true, then the recently tested formulations and dosages might achieve the desired effect; a reduction in beetle pressure.

Baiting of trees with synthetic attractants should be avoided in future studies due to possible differences in beetle pressure resulting from microclimate differences affecting elution rates. Likewise, artifically attracting beetles into treated and control trees may result in lower than expected treatment effects due to artifically high beetle pressure.

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